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PROBLEMS RELATED TO THE RESEARCH ON NEW LIGHT METAL ALLOYS

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Text of the slightly abbreviated lecture

In 1954 it was 100 years ago that professor Saint-Claire-Deville produced aluminum metal for the first time, thereby creating the basis for the industrial production of aluminum. At the beginning, on account of the high price, only jewelry was made from aluminum. During the first 10 years only 10 t of aluminum were produced, while in 1954 the production was over 3 million t. The price was reduced from 144,000 dollars per ton to 165 dollars per ton.

One of the greatest advantages of aluminum is that the metal can be produced in great purity which gives it properties both in the form of pure metal and alloys which can not be obtained with the customary purity of foundry aluminum. These properties are: the natural aging possibilities of the Al-Cu alloys, the great plasticity of 99.999% pure aluminum, and its excellent corrosion resistance.

By purifying foundry aluminum 99.999% pure aluminum can be produced. The great purity of aluminum or other metals can only be obtained by the most modern methods. These are based on the different solubilities of the impurities in the liquid or solid metal. Crystals containing small amounts of impurities in the liquid state can be made to push the impurities ahead of them.

To accomplish this 2 methods are used: (a) the Czochralski method, i.e., the slow extraction of the growing crystal from the smelting, and (b) melting in zones, i.e., recrystallization. In the latter case the heating unit travelling along the longitudinal axis of the metal bar will melt only a narrow area and will produce the same result. This process repeated several times will produce a very pure metal. The speed of the (a) extraction method and of the (b) method is very low, only a few 1/10 or 1/100 mm/minute.

The efficiency of the purification can be characterized by the distribution factor K of the impurities which is the quotient of the impurities of the solid and liquid phase ($K = 2\ C_{sol} : C_{liq}$). This of course varies with different metals and impurities. With such methods it was possible to produce 99.9999 and even 99.9[illegible] pure aluminum.

The desirable properties of an object produced from pure metal or alloy depend not only on purity, but to a large extent also on the quality of the casting. The quality of casting is one of the most important problems of smelting. For this purpose the semi and the fully continuous methods of casting with water cooling have been developed during the last 2 decades. This will give a branch-like texture in which the impurities are very evenly distributed in small quantities.

The quality of such bars can be characterized by Figure I on the abscissa of which the speed of solidification is marked. Thus the left side of the diagram corresponds to air cooled, the right side to continuous casting. As can be seen, in the latter not only the tensile strength but the elongation is also considerably greater, which improves plasticity.

The greatest hindrance to the even distribution of the alloying components is the already mentioned fact that solubility is different in the solid and liquid state. The result of this is separation within the granule, which manifests itself in the fact that the impurities are concentrated more toward the peripheries of the granules. This can be proved by testing the granules with a microsclerometer, see Figure 2. The impressions are more pronounced in the middle of the granules indicating less hardness, and fewer impurities. On the peripheries of the granule the situation is reversed.

Blocks cast by the continuous method show a new characteristic which is connected with the uneven distribution of the impurities. Careful observation during crystallisation (Figure 3) will show periodically repeating parallel clusters of lines about 1/10 mm apart. This phenomenon can be explained by examining the course of crystallisation. Impurities forced out by the growing crystal accumulate on the crystallisation front where they enrich the fusion. The solidifying point of this enriched fusion is lower. This is illustrated by Figure 4 (l_1 is the liquidus point of crystal s_1 ; l_1' and l' represent fusion enriched by impurities). Such enriched fusion solidifies at a lower temperature and may not even touch the main part of the fusion. The periodic repetition of this phenomenon leads to the aforementioned uneven distribution of the impurities.

Figure 5 shows the variations of the microhardness of an Al-Cu alloy with 4 % Cu at varying speeds of extension produced by the Czochralski method. At a speed of 2.5 mm/minute the change of hardness caused by periodic unevenness is considerable, while at a speed of 0.06 mm/minute it is rather small.

American investigators had similar experiences with germanium crystalls containing radioactive impurities, and experiences are similar also when examining the microstructure of an aluminum alloy after careful etching. The alloy shown in Figure 3 has been subjected to microhardness measurements; the results are shown in Figure 6. The periodic repetition of the microhardness waves is easily seen.

The uneven distribution of the impurities is the cause of the formation of the so-called substructure of the metals which is illustrated by Figure 7, which shows the microstructure of an Al-Cu alloy with 1.5 % Cu. The alloy was also made by the Czochralski method.

Due to the lack of time this problem can not be dealt with as extensively as it deserves. The recognition of the phenomenon of periodic separation is important both from a theoretical and a practical point of view, and if applied to continuous casting it will probably lead to significant results.

Let us now examine the development of the aluminum alloys. First of all those alloys will be discussed which guarantee great strength, good range of fatigue and operational safety.

Alloys with great strength of any structural composition -- same as in steel -- are built on solid solutions. Aluminum forms such solid solutions principally in its alloys with zinc, silver, magnesium, copper, and a few other metals.

The first important group of alloys of great strength was the duralumin group discovered by Wilm in 1907. It consisted of Al, Mg, Cu, and Mn. At the beginning only 0.4-0.6 % Mg was used;

later 3 times as much. In the case of duralumin with low Mg content the increased strength was due to the formation of $CuAl_2$; in the case of a higher Mg content Al_2CuMg was formed.

During World War II the Al-Mg-Zn alloy group was formed followed by the Al-Mg-Zn-Cu group. The latter, at the proper temperature and with artificial aging, has a good corrosion resistance which is superior to that of the Al-Mg-Zn alloy. The tensile strength of these alloys is 52-60 kg/sq mm.

The development of the jet plane posed new problems. Besides great initial strength that strength must now be capable of being maintained even when heated to 120-150° C. For this reason the Al-Mg-Zn-Cu alloys are not satisfactory because they loose their strength if heated beyond 120° C. So only the Al-Cu-Mg-Mn alloys can be considered, and only if they are artificially aged, because in case of natural aging at 100-130° C recrystallization takes place which greatly lowers the corrosion resistance. It is advisable that before aging it be given a few percent cold molding by rolling or drawing. This increases the tensile strength and corrosion resistance.

Theoretically other alloys could also be used for jet planes. In 1952 it was suggested in the US that the well-known Rolls-Royce alloys (RR-57: Cu, Mn alloy; RR-58: Cu, Fe, Mg, and Ni alloy) be tested for this purpose.

The present jet plane requirements however are so high that they can not be met by aluminum alloys. Therefore a new competitor has appeared, titanium. Titanium alloys have such superior properties that they could not even be approached by aluminum alloys.

Their melting points are much higher and their strength does not diminish so readily, as a result aluminum alloys have been eliminated from a very important field

In the new fields all reserves will have to be utilised which so far have either not been used at all or not to a sufficient extent. [Gyula Emod and doctor F. Erdman-Jesnitser (German Democratic Republic) joined in discussion.]

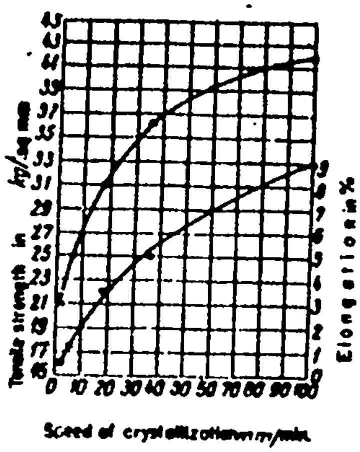

Figure 1

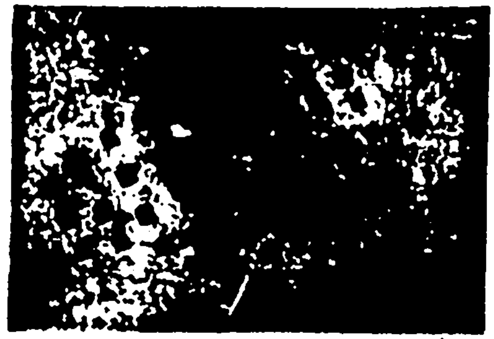

Figure 2

Figure 3a

Figure 3b

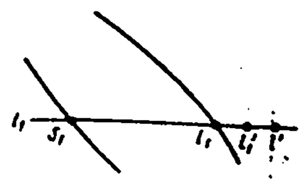

Figure 4

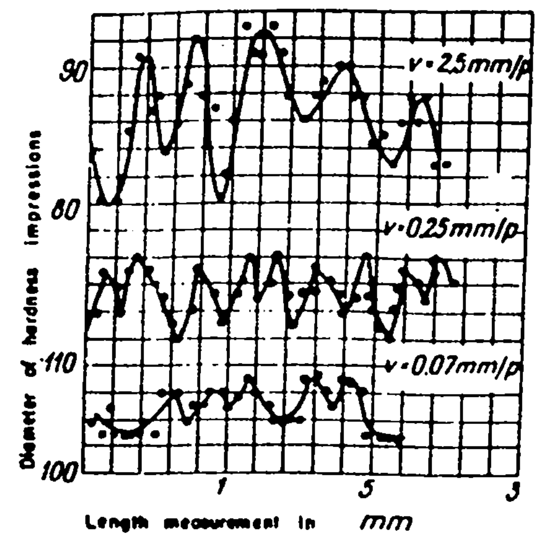

Figure 5

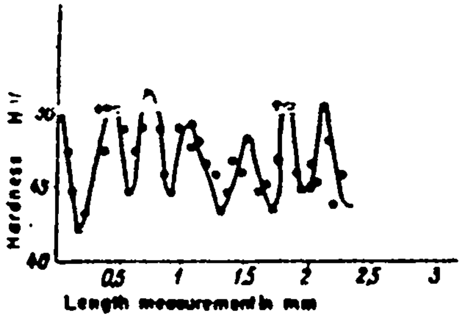

Figure 6

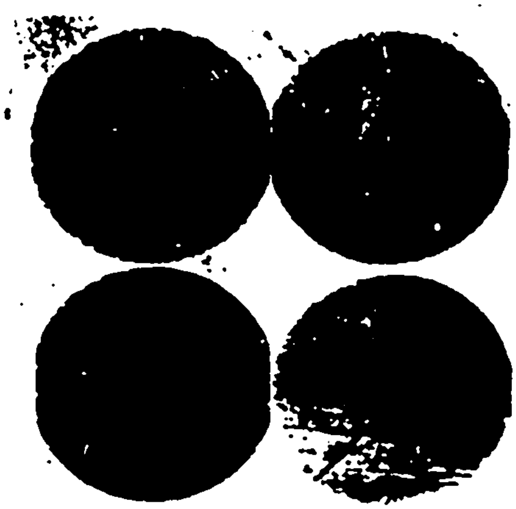

Figure 7